Efficiency Test of a 4 Cylinder 4 Cycle 20 H. P. Automobile Gasoline Engine

C. U. Smith

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EFFICIENCY TEST OF A FOUR CYLINDER FOUR CYCLE TWENTY HORSE POWER AUTOMOBILE GASOLINE ENGINE

A THESIS

PRESENTED BY

C. U. SMITH

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

MECHANICAL ENGINEERING

JUN 1908

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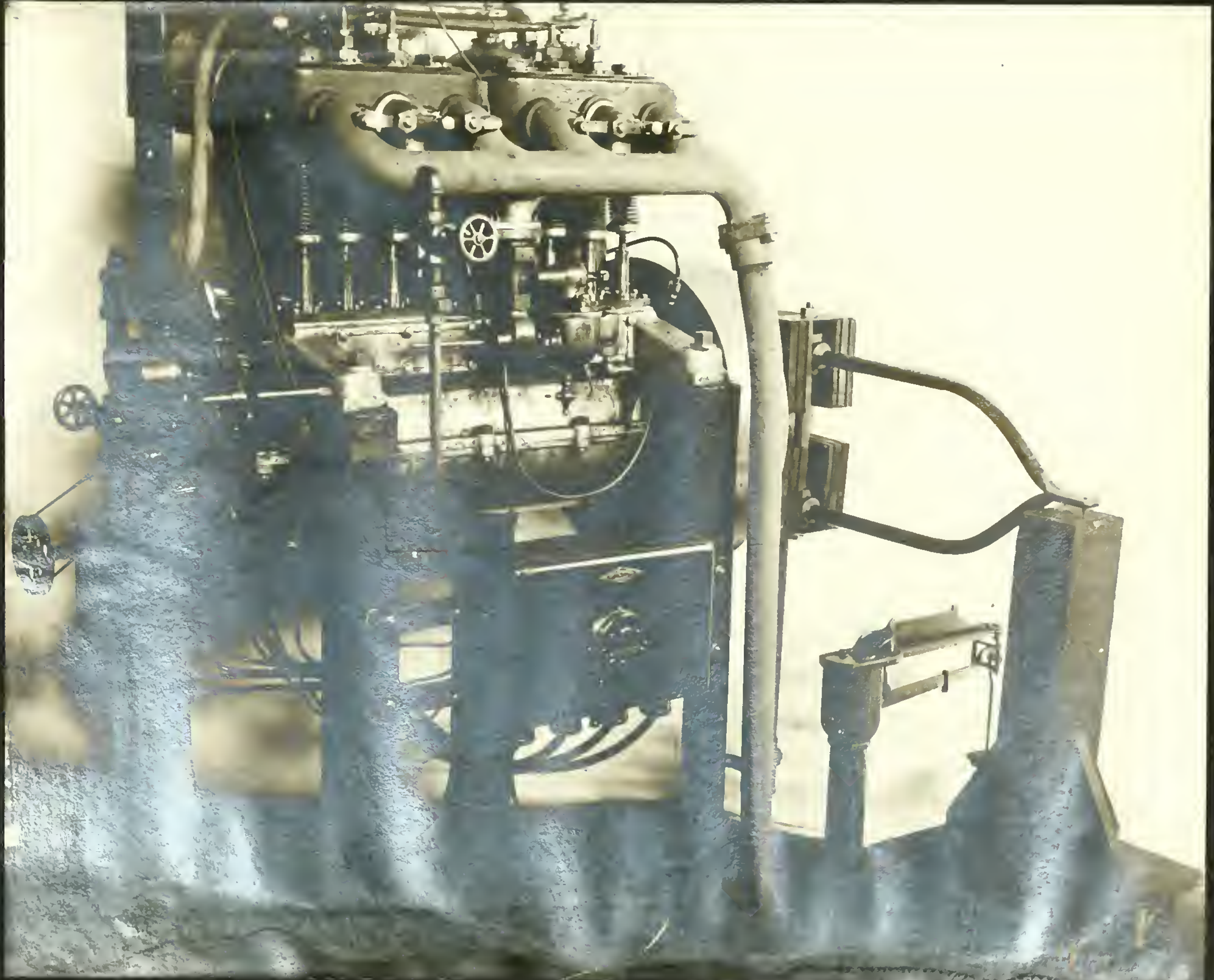

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Insert.

Section of Engine, valve side.

Efficiency Test of a Four Cycle, Four Cylinder,
Twenty Horse Power,
Gasoline Automobile Engine.

OBJECT: The object of this thesis is to show the efficiency of a twenty horse power automobile engine; this efficiency to be the highest obtainable on the lowest gasoline consumption.

APPARATUS: The apparatus used in the performance of this thesis consists of:

Four cylinder, four cycle, gasoline engine.
Lunkenheimer mixing valve.
McCord force feed oiler and copper tubing.
Splitdorf spark coil.
Gasoline tank and piping.
Prony brake.
Platform scale and weights.
Hand speed counter.
Thermometers. (212 F.)
Storage batteries.
Weighing tanks, scales and weights.
Piping and wiring.

Engine.

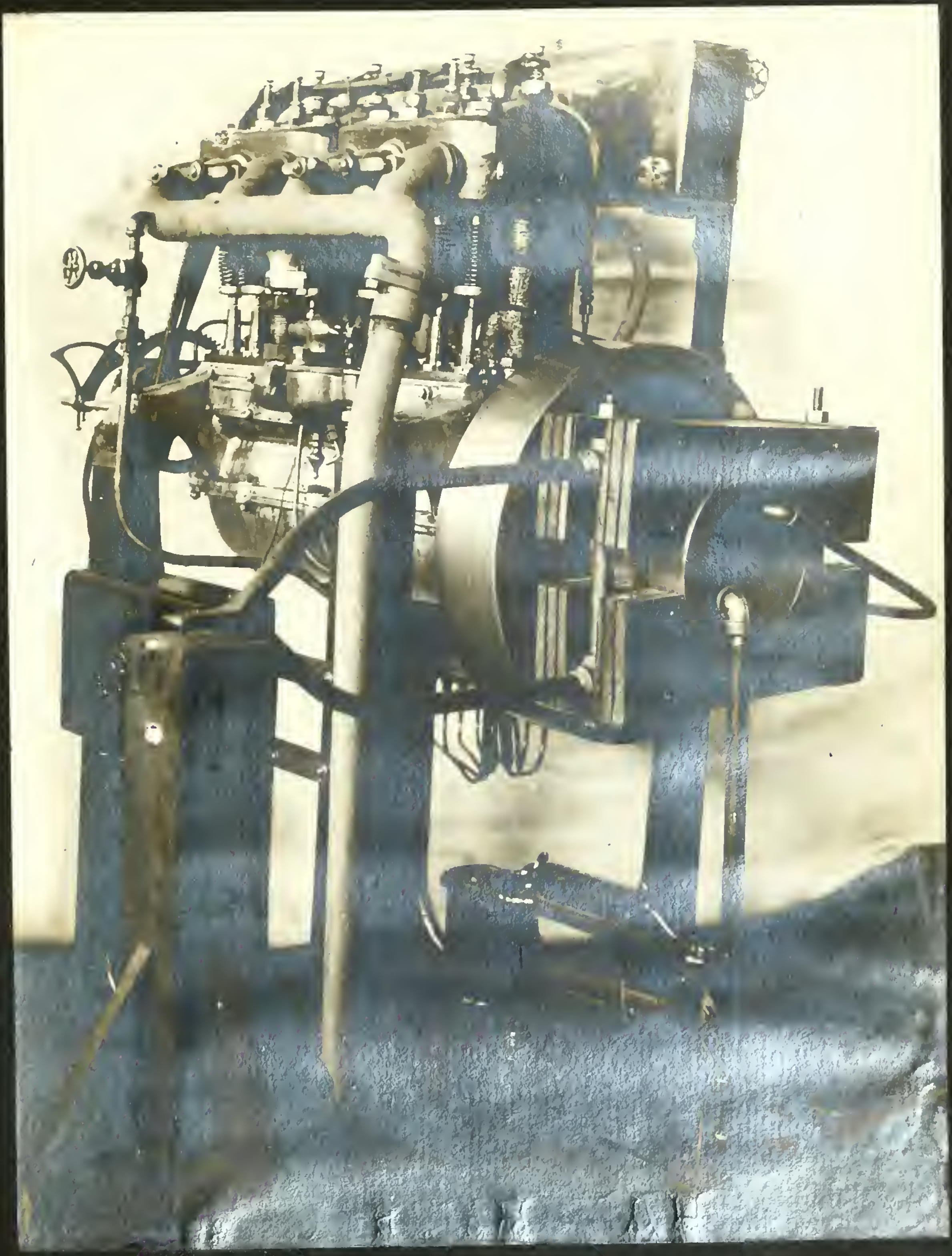
The engine is a four cylinder, four cycle, water cooled, gasoline engine, 4-3/8 in., bore by 4-3/4 in., stroke, made by the Continental Motor Mfg. Co. The cylinders are of iron cast in pairs and bolted to an aluminum crank case. The water jacket on the cylinders is 1/2 in. wide, and extends around the cylinders and the valves. It does not incase the cylinders all the way down to the crank case, but stops about half way, making all of the top part of the cylinder the cooled part. This is most necessary, because it is in the top of the cylinders that the explosions take place. The water entered at the bottom and passed out through the top. 7/8 in. brass tubing is used for the cooling water inlet and outlet.

The crank case is made in two parts. The upper part contains the cam shaft case and the hand holes for the crank case. There are also two hand holes in the cam case; four legs are cast on this part of the case to form the engine foundation. The lower

part of the case forms the bearing for the crank shaft and is fastened to the upper half by bolts. In the improved type of this engine the case does not act as a bearing, there being an extra casting used for this purpose, and the lower half of the case is bolted over it. By this means the crank case can be opened without disturbing the bearings.

The pistons are of the trunk type, made in the form of a hollow cylinder with one end open. They are fitted with three rings near the top, to insure a tight fit and to prevent leakage. Three oil rings are machined near the bottom of each piston to allow good distribution of the lubricant. On the inside of the pistons the wrist pins, 7/8 in. in diameter, are fastened by set screws, the upper ends of the connecting rods bearing on them. The wrist pins are made to fit very tightly and are forced into the pistons from the outside. The outer edges are beveled and are finished to clear the cylinder walls.

The crank shaft is 1 1/2 in. in diameter, made



of drop forged steel. On one end there is a 16-3/4 in. fly wheel weighing 96 lbs., and on the other is the gear for operating the cam shaft, and a pin for the starting crank. There are three bearings, one in the center, and one at each end. For convenience in referring to the cylinders they are numbered one, two, three, and four, four being on the end nearest the fly wheel. The cranks are made 180 degrees apart, one and four being up, when two and three are down, and vice versa.

The connecting rods are of the type in general use on auto engines, being of an I beam cross section with bearings at the ends for the wrist pin and the crank. A reference to the general drawing of the engine will give a good idea of the construction.

The cycle of events in this engine is the same as in all four cycle or four stroke engines. The events are: (1) the suction stroke during which the intake valve is open, (2) the compression or return stroke during which all valves are closed and the

charge is compressed ready for firing, (3) the working stroke resulting from the explosion and expansion of the charge, and (4) the return or exhaust stroke during which the exhaust valve is opened and the burned gases expelled.

Valves and Valve Setting.

The inlet and exhaust valves are on the same side of the engine, and are actuated by cams. These cams are pinned to the cam shaft which is operated by gears (in the ratio of seventy-two to thirty-six) from the main shaft.

The valves are of the mushroom type, ground to fit snugly on their seats. When lifted by the cams, they are returned to their original positions by coil springs placed on the outside of the engine. The valves do not bear directly on the cams, but are lifted by little forked push rods. One end of these rods is fitted with a roller that engages the cam, and the other end comes in contact with the end of valve stem.

The mixture enters the valve chamber through a Y pipe from the carburetor or mixing valve. Each fork

of the Y supplies two cylinders. The burned gases exhaust into one pipe, and pass through a long lead to the roof of the building.

The valve setting with which all runs for this thesis were made, is tabulated and the crank positions are shown on the blue prints.

Cylinder No. 1.

	Inlet valve.	Exhaust valve.
Opens.	21.675° late.	33.575° early.
Closes.	45.9° "	12.325° late.

Cylinder No. 2.

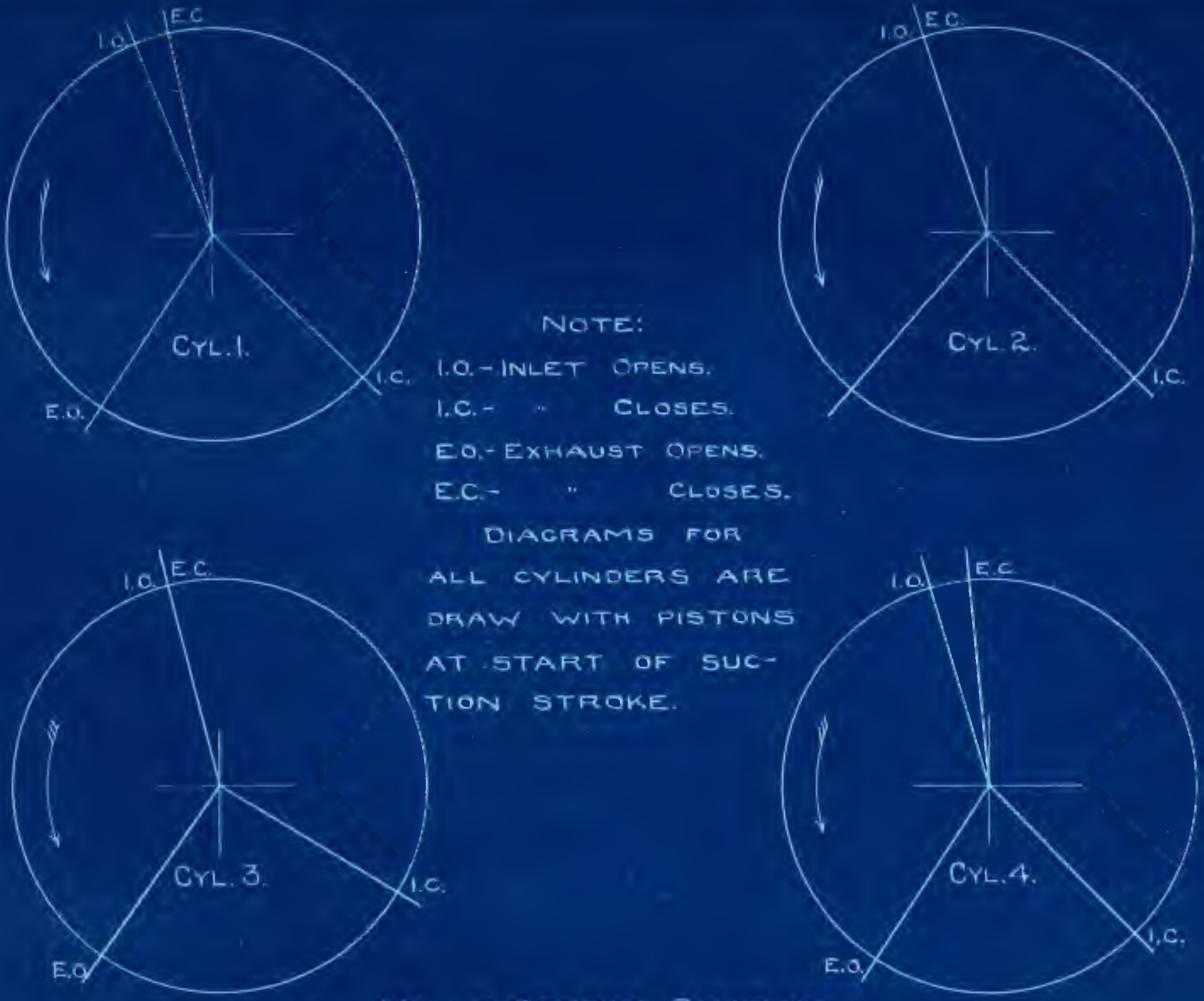
	Inlet valve.	Exhaust valve.
Opens.	17.425° late.	41.225° early.
Closes.	44.625° "	17.425° late.

Cylinder No. 3.

	Inlet valve.	Exhaust valve.
Opens.	13.6° late.	35.275° early.
Closes.	58.65° "	13.6° late.

Cylinder No. 4.

	Inlet valve.	Exhaust valve.
Opens.	16.15° late.	33.575° early.
Closes.	44.2° "	5.1° late.



NOTE:

I.O. – INLET OPENS.
I.C. – " CLOSES.
E.O. – EXHAUST OPENS.
E.C. – " CLOSES.

DIAGRAMS FOR ALL CYLINDERS ARE DRAW WITH PISTONS AT START OF SUCTION STROKE.

VALVE SETTING DIAGRAM.

C.U.S. '07.

Lubrication.

The engine is fitted with a complete system of lubrication. An eight point, force feed, McCord lubricator is operated by a small belt from the crank shaft of the engine.

This lubricator forces the oil through copper tubes to eight points on the engine. This distribution is one to each cylinder, one to each cam shaft bearing, and one to the center bearing of the crank shaft. The end bearings of the crank shaft are lubricated by grease cups, screwed into the casting.

Further lubrication is had by filling the crank case with oil to such a level, that the ends of the connecting rods hit the oil surface, and splash it over the bearings and lower part of the cylinders.

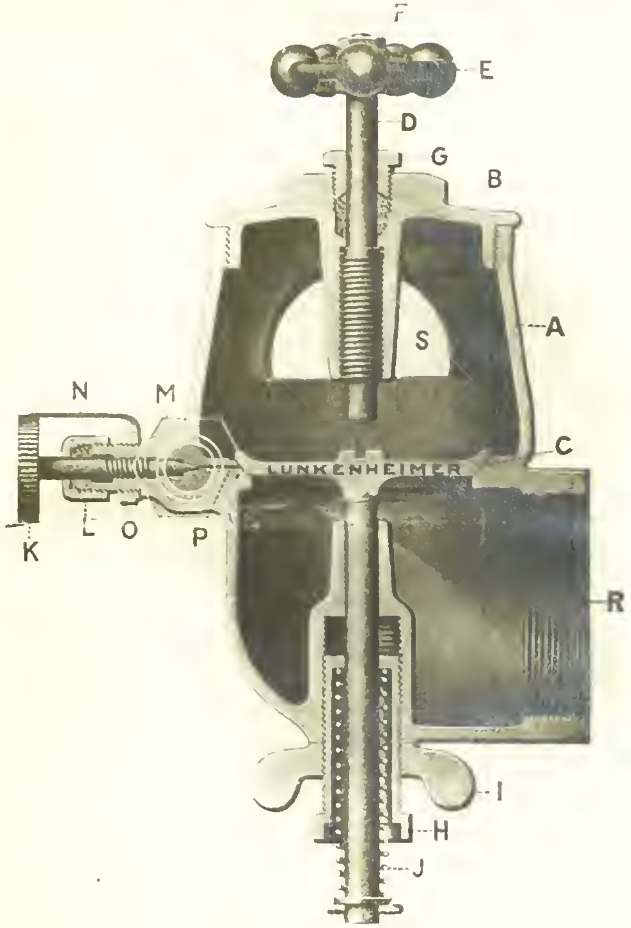
Mixing Valve.

The engine is fitted with a Lunkenheimer mixing valve, instead of a carburetor ordinarily used on automobile engines. This method of vaporization was found to be more efficient for such a test, than the use of a carburetor.

The valve is very simple in its operation, and is best explained by reference to the sectional view of the same. It is made entirely of brass so that the gasoline can have no corrosive action upon it.

When the piston is on its suction stroke the partial vacuum causes the disc C to open against the pressure of the spring J which pressure is best regulated by trial when the engine is in operation. The movement of the disc is also limited by the stem D. When the disc is raised the gasoline port P in the side of the valve seat is uncovered and an amount of gasoline is sprayed into the incoming volume of air rushing into the valve and is immediately vaporized or gasified. When the suction is released the disc returns to its original position, and shuts off the flow of gasoline.

The small needle valve K, that controls the flow of gasoline to the gasoline inlet P, has a long taper bearing and the stem threads are of fine pitch; thus very close adjustment can be secured, and the amount of gasoline injected can be regulated to a nicety.


F
E
D
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C
LUNKENHEIMER
K
L
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H
J

The wheel handle of the needle valve is engraved with numbers to show the different degrees of opening, and it requires but little instruction to enable an inexperienced operator to properly manipulate the valve.

It will be noticed that the wheel handle of the needle valve has a flat spot on its periphery which the spring N engages. The object of this is to enable the operator, after the needle valve has been properly adjusted for the correct mixture, to at any time easily obtain this same adjustment should the needle valve be closed or open beyond the proper setting. No matter where this flat spot may be after the needle valve has been set, the spring N can be brought to bear on same, by merely loosening the lock nut O, which will permit of the free turning of the spring.

The lift of the disc can be easily regulated by means of the brass wheel at the top, which also regulates the speed of the engine. When the engine is not in use, the gascline needle valve should be immediately closed, to guard against the leakage of gasoline. The gasoline inlet is provided with a union M, which

facilitates its connection to the pipe.

Gasoline Tank.

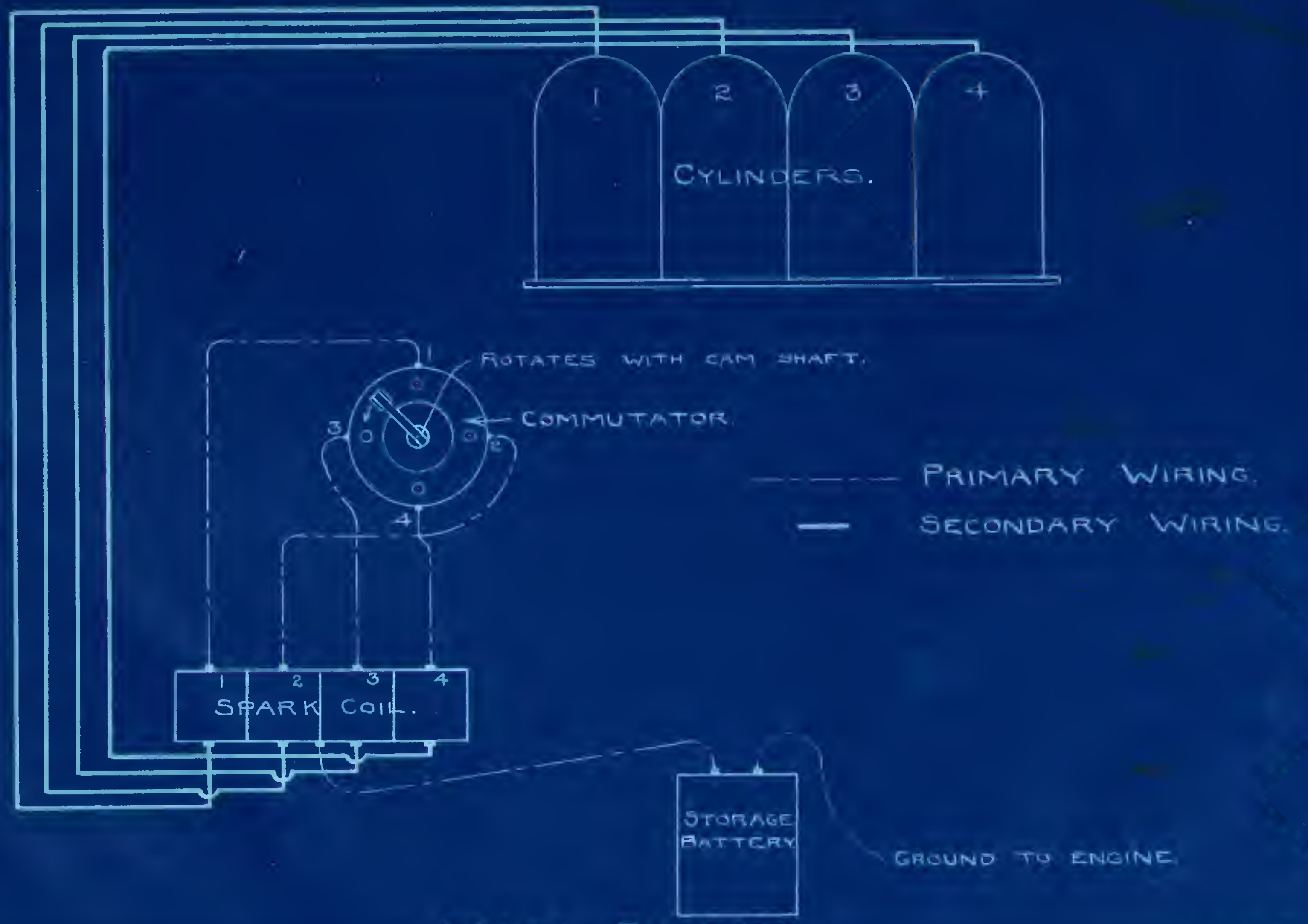
The gasoline is supplied from a copper tank, 4"x 7"x22". This tank has a glass gauge on the side extending diagonally across, from top to bottom, and fitted with a scale calibrated to read to thousandths of a cubic foot.

The gasoline is supplied at the top through a 2" opening. This is fitted with a screw cap vented to the atmosphere. A fitting at the bottom of the tank furnishes the connection to the copper tubing leading to the mixing valve. Just below the tank a stop cock is inserted in the line, for shutting off the supply.

Ignition.

The ignition is of the jump spark type, in common use on engines of this design. A diagram of the wiring shows how the connections are made.

The spark plugs used are of mica insulation, with platinum points. They fit into the valve cover of the intake valve box. They are sparked by the current from a Splitdorf spark coil. The intensity of the spark is



WIRING DIAGRAM.

regulated, from the coil, by means of the contact screws. In this adjustment it is best to have the least possible tension on the vibrator spring.

The current is furnished from storage batteries. One lead is grounded on the engine and the other is connected to the binding post on the coil. From the commutator the primary or low tension wires are run to the coil, and from there, the secondary or high tension wires are led to the spark plugs.

The commutator or timer is made of fiber, with the permanent contact points set in an outer disc. This disc is movable about its axis and can be shifted back and forth by a bar and lever moving over a divided sector. By this movement the spark can be retarded or advanced. The contact bar is permanently fastened to one end of the cam shaft and in passing the points on the outer disc causes a spark. The order of firing the cylinders is; one, three, four and two.

Prony Brake.

The Prony brake is of the ordinary type consisting of two built up wood blocks, held together

by 1/2" bolts and fitted at one end with an arm made of 1" pipe. This arm rests on the block or strut on the scale and to eliminate any unnecessary vibration it is made free to move in a horizontal plane. The load is applied by clamping the blocks together with the bolts and nuts.

This Prony brake is attached to a water cooled brake pulley, 8-1/2" in diameter and having a 5" face. The pulley fits on the crank shaft and is bolted to the face of the fly wheel.

The other apparatus needs no special description as everything is of standard make and design used in general experimental and laboratory work.

All of the machine work and small fittings on the engine were carried on in the machine shop of the Armour Institute. The castings were obtained from a local shop. The engine is bolted to a cast iron frame, having a base 22"x33", with four uprights two feet high carrying the engine.

METHOD OF PROCEEDURE: Before running any tests on the engine it was necessary to have it properly set up

and in good running order . This was all included in the preliminary thesis work and is here described.

The engine was turned over to the Mechanical Department from the machine shop, bolted to its base and with the mechanical parts all assembled. It was then necessary to permanently locate the engine and attach the required fittings.

It was first essential to secure the engine to a permanent foundation. Four holes were bored in the cast iron base and then the distances between their centers was laid down on the floor, where it was desired to place the anchor bolts. Holes were drilled through the concrete floor and half inch bolts were put in place. A templet was used to obtain the correct distances between the bolts and to hold them at the required height. Cement was then poured into the holes, around the bolts, and allowed to set, after which the templet was removed and the cement finished flush with the floor.

The engine and base were then put in position and blocked up about an inch from the floor, to leave room for the cement foundation. A hand level was used on the engine, which was set by means of

blocks and shims to rest level an inch above the floor. A wood frame was then made around the engine, to contain the cement, which was mixed thin and poured under the base. It was allowed to set for a day and then the frame was removed and the foundation was finished flush with the iron base. When the cement was thoroughly set the nuts were screwed onto the anchor bolts and the engine was securely fastened to its foundation.

Holes were next bored in the legs of the foundation for the bolts to support the oiler and spark coil struts . The engine goundation and base were painted with green enamel and allowed to dry.

The struts were bolted to the base, parallel to the axis of the engine and the oiler and spark coil were then attached to these. The copper tube leads, from the oiler to the cylinders and bearings were put in place. To fit this tubing, a wire templet was made for each lead, the tubing was cut to the proper length and threaded on each end. As the tubing was very stiff the temper was drawn out, after which the couplings were attached and the tubes bent as necessary and fastened in place.

The wiring was next done. Small primary wire was cut to the required length, fitted with terminals and attached from the commutator to the coil. Heavily insulated wire was used for the secondary wiring, running from the coil to the spark plugs. All wires were taped together neatly and wherever necessary extra insulation was provided.

For the cooling water inlet and exhaust piping 1/2" pipe was used. The arrangement for the piping was such that a tee was placed in the inlet pipe to supply cooling water for the brake and also for the exhaust gas pipe. Globe stop valves were placed in the inlet pipe, in the leads to the exhaust pipe and brake pulley and in the exhaust water pipe. The cooling water from the engine was piped to the weighing tanks and from the brake pulley to the waste pipe. 1-1/4" pipe was used for the exhaust gases and was led from the engine to a main exhaust, leading to the roof of the building.

A Schebler carburetor was attached to the engine and with gasoline supplied from a temporary tank, the

engine was run. When the cooling water was turned on several leaks were noted and repaired.

The engine was run to wear it down and while in operation a decided knock was noticed. An investigation proved that the lower ends of the connecting rods were hitting the crank case, as the clearance was insufficient. To remedy this, it was necessary to dismantle the engine, turn it over on a temporary support, take off the bottom of the crank case and chisel the case out where there were indications of knocking. A very liberal clearance was allowed.

This completed, the engine was again put in place and all connections made as before. The engine was then run several times but the carburetor was found to need adjustment. After various attempts to get good results with the carburetor it was abandoned and a Lunkenheimer mixing valve was substituted. This was found to give good results and the tests were then made.

On all tests the engine was started with no load and as the load was applied the spark was advanced, to increase the speed. The speed of the engine was also

increased by raising the stem, on the mixing valve, controlling the travel of the valve disc. By adjustment of the mixing valve and the spark, the engine was made to carry varying loads.

During these tests readings were taken, at intervals of ten minutes, of the R. P. M., the brake load, the scale on the gasoline tank, the weight of the cooling water, and the temperatures of the inlet and outlet cooling water, the gasoline and the air in the room.

On all of the runs, but No. 7, the spark was advanced to its maximum and the mixture set to give, supposedly, the best results. In the one exception the spark was retarded to note its effect on the operation of the engine. From the data obtained during these runs all the results given on the final log sheet were figured.

Log sheets are included in this thesis showing the data recorded during the run and also that which was calculated.

A heat distribution diagram was drawn and

four curves were plotted. The diagram was drawn as follows: The B. H. P. were laid out as abscissae and the heat supplied, total in per cent, was used as the ordinate. The heat equivalent was first laid of for the desired horse power and then added to this the per cent of heat rejected in the jacket water was laid off. All above this curve was then considered heat rejected in exhaust and lost through radiation and incomplete combustion.

The four curves were plotted to show the relation of the brake horse power to (1) revolutions per minute, (2) thermodynamic efficiency, (3) gallons of gasoline per B. H. P., and (4) B. T. U. per B. H. P. per minute.

In order to have the method of obtaining the results shown in the logs a sample calculation of one run will be included . All other runs were calculated in the same manner and as the method is well shown by one illustration it is not considered necessary to show the entire calculations.

DATA: The results shown on the result log sheets were figured from the data given on the running log sheets. To show how the results were obtained the complete calculations for run No. 4 are here given.

Sample Calculations.

Gasoline consumed, total, cu. ft. Difference of scale readings on gasoline tank. .1495 - .022 = .1275

Gasoline consumed, total, gals. 7.48 gals. = 1 cu. ft. 7.48 x .1275 =.955 gals.

Gasoline consumed, total, lbs. One cu. ft. of water weighs 62.425 lbs. Specific gravity of the gasoline, as determined with a hydrometer, was .7175. 62.425 x .7175 = 44.75 lbs., weight of one cu. ft. of gasoline. 44.75 x .1275 = 5.71 lbs.

Calorific value of gasoline. Furnished by the Standard Oil Co. by reference to the specific gravity. 19000 B. T. U. per lb.

Jacket water supplied, total, lbs. By weight. 536 lbs.

All quantities per hour were obtained by multiplying by two, where the run was for thirty minutes.

All temperatures were taken with standard 212 degree F. thermometers.

The revolutions per minute were taken with a hand speed counter.

The explosions per minute were twice the number of revolutions, as there are two explosions to every revolution of a four cylinder, four cycle engine.

The builders' rating was taken as the horse power that the Continental Motor Mfg. Co. rate the engine at.

Actual brake horse power. 2xπxrxNxP/33000 = B.H.P.

where r = brake arm length in feet = 2.096 ft.

N = R. P. M. = 722.75

P = Net brake load = 52 - 2 = 50 lbs.

2xπx2.096x722.75x50/33000 = 14.37 B. H. P.

Dead weight on scales = 2.86 - .86 = 2lbs.

Heat supplied per hour. Heating value per lb. x number of lbs. per hour. 19000 x 11.42 = 216,800 B.T.U.

B. T. U. per B. H. P. per hour. 216,800/14.37 = 15,080.

B. T. U. per B. H. P. per minute. 15,080/60 = 251.33.

Thermodynamic efficiency per B. H. P. and heat equivalent of B. H. P. 2545/B.T.U. per B.H.P. per hr. = 2545/15080 = .169 .169 x 100 = 16.9%

The gasoline consumed per B. H. P. per hour was obtained by dividing the gasoline consumed per hour by the B. H. P.

Heat rejected in jacket water. Pounds of jacket water per hour x difference in temperature of the inlet and outlet/total heat supplied per hour. 1072 (103 - 52)/ 216800 = .2525 .2525 x 100 = 25.25%

m Heat rejected in exhaust and lost through radiation and incomplete combustion. Obtained by difference. 100 - (16.9 + 25.25) = 57.85%.

DISCUSSION AND CONCLUSION: During the first part of the testing carburetors were used on the engine. They were found to be too delicate, in operation, for such a test. In automobile work the engine is subject to sudden and varying loads, therefore the carburetor cannwell be used. The carburetor that is sensitive enough to act for all the fluctuations is to the gasoline engine as the governor is to the steam engine.

When a constant load is applied and all the conditions are constant the use of a valve, that will give an unvarying mixture when once set, is the vaporizer to be desired. The Lunkenheimer mixing valve met just this requirment.

Throughout the test it has been the object to obtain a variety of runs in the allotted time. For this reason the runs were not all made under one fixed set of conditions. For example, if there had been more time, the runs would have been one hour long, the cooling water would have been regulated to the same quantity and temperatures for a number of runs and the spark would have been changed for the same mixture on each run. Then there would be a series of tests with from six to ten runs in each series.

The lack of time to obtain more varied results was due to the facts that it was necessary to assemble and connect the engine and its fittings, make the foundation and alter the crank case. The time spent in trying to obtain results withna carburetor was considerable and on several occasions it was

necessary to make changes on the engine and its accessories, which while not of major importance occupied time.

From the results it is noted that the gasoline consumption, for the low horse powers, is very high, while for Runs No. 4, 5, and 6, the consumption is better. This shows that the engine is operating most economically on a heavy load.

On all the runs when the load was applied, the mixture was throttled to give the least gasoline consumption. Whenever the mixture was below that used in the test the engine throttled itself and would not carry the load.

By reference to the operation of the engine throughout the test it is in every respect perfect and if more time was available good results could be obtained consistently. A few changes that might be of help in obtaining better results would be, to use a different design of timer or commutator, and to change the setting of the valves. The present setting of the exhaust valves is good, but if the inlet opened and and closed a trifle earlier the results would be better.

Armour Institute of Technology.

Automobile Engine Test.

Running Log Sheet.

Run No. 1.

	Temperatures degrees F.								Gasoline tank
Time.	Gas.	Inlet	Outlet	Room	R. P. M.	Brake load.	Net load.	Water.	readings.
10:00	73	52	100	79	627	28.2	26.2	517	.067
:10	76.5	53	101	79	629	28.22	26.22		.107
:20	80	53	102	79	627	28.22	26.22		.149
:30	80	52	102	79	627	28.22	26.22	1061	.190
Aver.	77.25	52.5	101.25	79	627.5	28.215	26.215	544	.123

Run No, 2.

4:15	76	52	80	76	836	17	15	541	.134
:25	77	52	82	76	833	17	15		.174
:35	77	52	81	76	838	17	15		.213
:45	78	52	81	76	837	17	15	1551	.250
Aver.	77	52	81	76	836	17	15	1010	.116

Observer:

C. U. Smith

Armour Institute of Technology.

Automobile Engine Test.

Running Log Sheet.

Run No. 3.

	Temperatures degrees F.								
Time.	Gas.	Inlet	Outlet	Room	R. P. M.	Brake load.	Net load.	Water.	Gasoline tank readings.
11:00	67	51.5	87	75	716	35.7	33.7	522	.0015
:10	68.5	51.5	86	75	667	"	"		.0505
:20	66.5	51.5	86.7	75	647	"	"		.0945
:30	75	51.5	87	76	637	"	"		.14
:40	74	51.5	85	76.5	640	"	"		.1856
:50	79	51.5	86	77	583	"	"		.198
12:00	80	52	87	77	620	"	"	1895	.2495
Aver.	74.28	51.57	86.39	76	644.28	"	"	1373	.248

Added 1000 c, c. gasoline = cu.ft.= .0353

Total gasoline.= .2833

Observer:

C. H. Smith.

Armour Institute of Technology.

Automobile Engine Test.

Running Log Sheet.

Run No. 4.

	Temperatures degrees F.								
Time.	Gas.	Inlet	Outlet	Room	R. P. M.	Brake load.	Net load.	Water.	Gasoline tank readings.
9:20	66	52	103	69	720	52	50	500	.022
:30	67	52	103	69	724	"	"		.0645
:40	68	52	103	69	722	"	"		.1071
:50	67	52	103	69	725	"	"	1036	.1495
Aver.	67	52	103	69	722.75	"	"	536	.1275

Run No. 5.

10:35	73	53	86	71	630	44	42	501	.1125
:45	74	52	86	71	620	"	"		.165
:55	73	52	85	72	620	"	"		.146
11:05	73	52	86	72	620	"	"	1455	.196
Aver.	73,25	52.25	85.75	71.5	622.5	"	"	904	.0835

Added 2000c.c. gasoline

Total gasoline for run .15375

Run No. 6.

11:30	77	52	90	75	715	30.5	28.5	520	.127
:40	77	52	93	75	714	"	"		.174
:50	77	52	93	75	720	"	"		.220
12:00	78	52	92	75	716	"	"	1075	.268
Aver.	77.25	52	92	75	716.25	"	"	555	.141

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Automobile Engine Test.

Running Log Sheet.

Run No. 7.

Time.	Temperatures degrees F. Gas.	Inlet	Outlet	Room	R. P. M.	Brake load.	Net load.	Water.	Gasoline tank readings.
2:10	69	52	89	72	650	22	20	501	.016
:20	71	52	90	72	654	"	"		.0525
:30	73	52	91	73	654	"	"		.0855
:40	73	52	91	73	656	"	"	1329	.1260
Aver.	71.5	52	90.25	72.5	654.5	"	"	891	.110

Run No. 8.

Time.	Temperatures degrees F. Gas.	Inlet	Outlet	Room	R. P. M.	Brake load.	Net load.	Water.	Gasoline tank readings.
4:10	73	52	96.5	71	750	32.5	30.5	505	.03
:20	72	52	98	71	745	"	"		.077
:30	73	52	98	71	748	"	"		.125
:40	73	52	99	71	751	"	"	1182	.172
Aver.	72.75	52	97.95	71	748.5	"	"	677	.142

Observer:

C. U. Swett.

Armour Institute of Technology.

Automobile Engine Test.

Result Log Sheet.

Date........... May, 27, 1907.
Run No......... 1

Duration of run	mins.	30
Gasoline consumed, Total	cu. ft.	.123
" " "	gals.	.921
" " "	lbs.	5.51
Calorific value of gasoline.	.B. T. U. per Lb.	19000
Jacket water supplied, Total	lbs.	544
Gasoline consumed per hour	cu. ft.	.246
" " " "	gals.	1.842
" " " "	lbs.	11.02
Jacket water supplied per hour	lbs.	1088
" " inlet	°F.	52.5
" " outlet	°F.	201.25
Gasoline in tank	°F.	77.25
Air in room	°F.	79
Revolutions per minute		627.5
Explosions " "		1255
Builders' rating	H.P.	20
Actual brake horse power	H. P.	6.56
Heat supplied per hour	B.T.U.	209,500
B. T. U. per B. H. P. per hour		31,917.6
" " " " minute		531.95
Thermodynamic efficiency per B. H. P.	%.	7.97
Gasoline per B. H. P.	cu. ft.	.0375
" " "	gals.	.2812
" " "	lbs.	1.66
Heat equivalent of B. H. P.	%.	7.97
" rejected in jacket water	%.	25.36
" " " exhaust and lost through radiation and incomplete combustion	%.	66.67

Observer:

C. H. Smith

Armour Institute of Technology.

Automobile Engine Test.

Result Log Sheet.

Date		May, 28, 1907.
Run No.		2
Duration of run	mins.	30
Gasoline consumed, Total	cu. ft.	.116
" " "	gals.	.868
" " "	lbs.	5.19
Calorific value of gasoline	B. T. U. per lb.	19000
Jacket water supplied, Total	lbs.	1010
Gasoline consumed per hour	cu. ft.	.232
" " " "	gals.	1.736
" " " "	lbs.	10.38
Jacket water supplied per hour	lbs.	2020
" " inlet	°F.	52
" " outlet	°F.	81
Gasoline in tank	°F.	77.1
Air in room	°F.	76
Revolutions per minute		836
Explosions " "		1672
Builders' rating	H.P.	20
Actual brake horse power	B.H.P.	5
Heat supplied per hour	B.T.U.	197,000
B."T. U."per B."H. P. per hour		39,400
" " " " minute		656.33
Thermodynamic efficiency per B. H. P.	%.	6.47
Gasoline per B. H. P. per hour	cu. ft.	.04635
" " " " "	gals.	.372
" " " " "	lbs.	2.073
Heat equivalent of B. H. P.	%.	6.47
" rejected in jacket water	%.	29.75
" " " exhaust and lost through radation and incomplete combustion	%.	63.78

Observer:

C. W. Smith

Armour Institute of Technology.

Automobile Engine Test.

Result Log Sheet.

Date		May, 29, 1907.
Run No.		3
Duration of run	mins.	60
Gasoline consumed, Total	cu. ft.	.2833
" " "	gals.	2.12
" " "	lbs.	12.67
Calorific value of gasoline	B. T. U. per lb.	19000
Jacket water supplied, Total	lbs.	1373
Gasoline consumed per hour	cu. ft.	.2833
" " " "	gals.	2.12
" " " "	lbs.	12.67
Jacket water suppied per hour	lbs.	1373
" " inlet	°F.	51.57
" " outlet	°F.	86.39
Gasoline in tank	°F.	74.28
Air in room	°F.	76
Revolutions per minute		644.28
Explosions " "		1288.56
Builders' rating	H.P.	20
Actual brake horse power	B.H.P.	8.64
Heat supplied per hour	B.T.U.	241,000
B.T.U. per B.H.P. per hour		35,950
" " " " minute		401.66
Thermodynamic efficiency per B. H. P.	%.	7.08
Gasoline per B. H. P. per Hour	cu.ft.	.03278
" " " " "	gals.	.2455
" " " " "	lbs.	1.467
Heat equivalent of B. H. P.	%.	7.08
" rejected in jacket water	%.	19.85
" " " exhaust and lost through radiation and incomplete combustion	%.	73.07

Observer:

C. W. S

Armour Institute of Technology.

Automobile Engine Test.

Result Log Sheet.

Date...............May, 31, 1907.
Run No............................4
Duration of run..........................mins. 30
Gasoline consumed, Total................cu. ft. .1275
" " " ....gals. .955
" " " ....lbs. 5.71
Calorific value of gasoline...B. T. U. per lb. 19000
Jacket water supplied, Total...............lbs. 536
Gasoline consumed per hour..............cu.ft. .255
" " " " ....gals. 1.91
" " " " ....lbs. 11.42
Jacket water supplied per hour............lbs. 1072
" " inlet.........................°F. 52
" " outlet........................°F. 103
Gasoline in tank..........................°F. 67
Air in room...............................°F. 69
Revolutions per minute.......................722.75
Explosions " " 1445.5
Builders' rating..........................H.P. 20
Actual brake horse power................B.H.P. 14.37
Heat supplied per hour..................B.T.U. 216,800
B. T. U. per B. H. P. per hour................. 15,080
" " " " minute..............251.33
Thermodynamic efficiency per B. H. P........%. 16.9
Gasoline per B. H. P. per hour..........cu.ft. .0177
" " " " " ....gals. .1328
" " " " " ....lbs. .794
Heat equivalent of B. H. P...................%. 16.9
" rejected in jacket water..............%. 25.25
" " " exhaust and lost through
radiation and incomplete combustion........%. 57.85

Observer:

Armour Institute of Technology.

Automobile Engine Test.

Result Log Sheet.

Date	June, 3, 1907.	
Run No.		5
Duration of run	min.	30
Gasoline consumed, Total	cu. ft.	.15375
" " "	gals.	1.149
" " "	lbs.	6.88
Calorific value of gasoline	B. T. U. per lb.	19000
Jacket water supplied, Total	lbs.	904
Gasoline consumed per hour	cu. ft.	.30750
" " " "	gals.	2.298
" " " "	lbs.	13.76
Jacket water supplied per hour	lbs.	1808
" " inlet	°F.	52.25
" " outlet	°F.	85.75
Gasoline in tank	°F.	73.25
Air in room	°F.	71.5
Revolutions per minute		622.5
Explosions " "		1245
Builders' rating	H.P.	20
Actual brake horse power	B.H.P.	10.4
Heat supplied per hour	B.T.U.	261,500
B. T. U. per B. H. P. per hour		25,140
" " " " "		435.83
Thermodynamic efficiency per B. H. P.	%.	9.73
Gasoline per B. H. P. per hour	cu. ft.	.02953
" " " " "	gals.	.2207
" " " " "	lbs.	1.322
Heat equivalent of B. H. P.	%.	9.73
" rejected in jacket water	%.	23.18
" " " exhaust and lost through radiation and incomplete combustion	%.	67.09

Observer:

C. W.

Armour Institute of Technology.

Automobile Engine Test.

Result log Sheet.

Date		June, 3, 1907.
Run No.		6
Duration of run	min.	30
Gasoline consumed, Total	cu. ft.	.141
" " "	gals.	1.055
" " "	lbs.	6.315
Calorific value of gasoline	B. T. U. per lb.	19000
Jacket water supplied, Total	lbs.	555
Gasoline consumed per hour	cu. ft.	.282
" " " "	gals.	2.11
" " " "	lbs.	12.63
Jacket water supplied per hour	lbs.	1110
" " inlet	°F.	52
" " outlet	°F.	92
Gasoline in tank	°F.	77.25
Air in room	°F.	75
Revolutions per minute		716.25
Explosions " "		1432.5
Builders' rating	H.P.	20
Actual brake horse power	B.H.P.	8.15
Heat supplied per hour	B.T.U.	240,000
B. T. U. per B. H. P. per hour		29,480
" " " " minute		491.33
Thermodynamic efficiency per B. H. P.	%.	8.65
Gasoline per B. H. P. per hour	cu.ft.	.0346
" " " " "	gals.	.259
" " " " "	lbs.	1.551
Heat equivalent of B. H. P.	%.	8.65
" rejected in jacket water	%.	18.52
" " " exhaust and lost through radiation and incomplete combustion	%.	72.83

Observer:

Armour Institute of Technology.

Automobile Engine Test.

Result Log Sheet.

Date		June, 3, 1907.
Run No.		7
Duration of run	mins.	30
Gasoline consumed, Total	cu. ft.	.110
" " "	gals.	.824
" " "	lbs.	4.925
Calorific value of gasoline	B. T. U. per lb.	19000
Jacket water supplied, Total	lbs.	891
" " inlet	°F.	52
" " outlet	°F.	90.25
" " supplied per hour	lbs.	1782
Gasoline consumed per hour	cu. ft.	.220
" " " "	gals.	1.648
" " " "	lbs.	9.85
Gasoline in tank	°F.	71.5
Air in room	°F.	72.5
Revolutions per minute		654.5
Explosions " "		1309
Builders' rating	H.P.	20
Actual brake horse power	B.H.P.	5.215
Heat supplied per hour	B.T.U.	187,100
B. T. U. per B. H. P. per hour		35,910
" " " " minute		598.5
Thermodynamic efficiency per B. H. P.	%.	7.08
Gasoline per B. H. P. per hour	cu. ft.	.0422
" " " " "	gals.	.316
" " " " "	lbs.	1.894
Heat equivalent of B. H. P.	%.	7.08
" rejected in jacket water	%.	36.4
" " " exhaust and lost through radiation and incomplete combustion	%.	56.58

Observer:

C U. Smith

Armour Institute of Technology.

Automobile Engine Test.

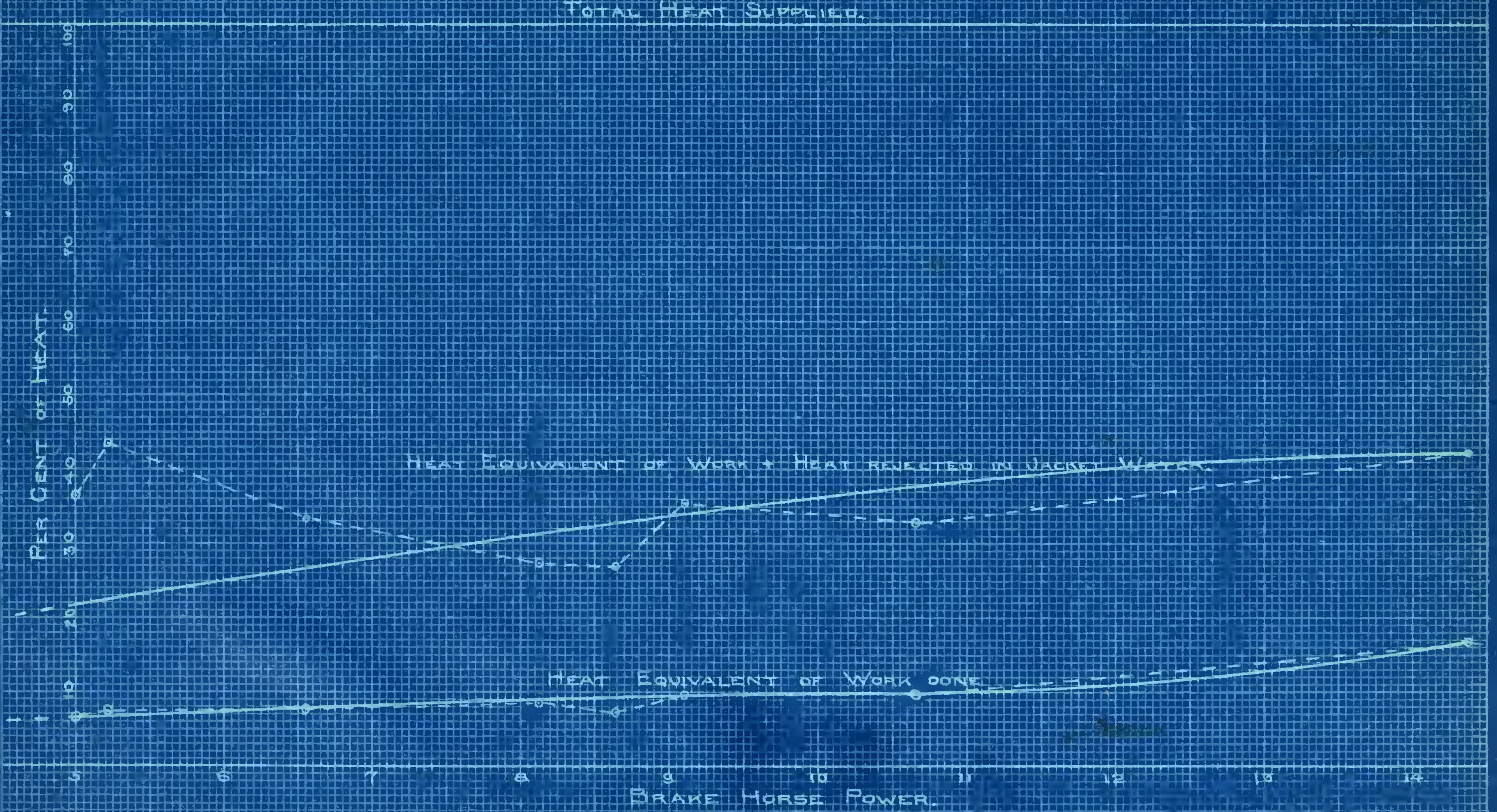
Result Log Sheet.

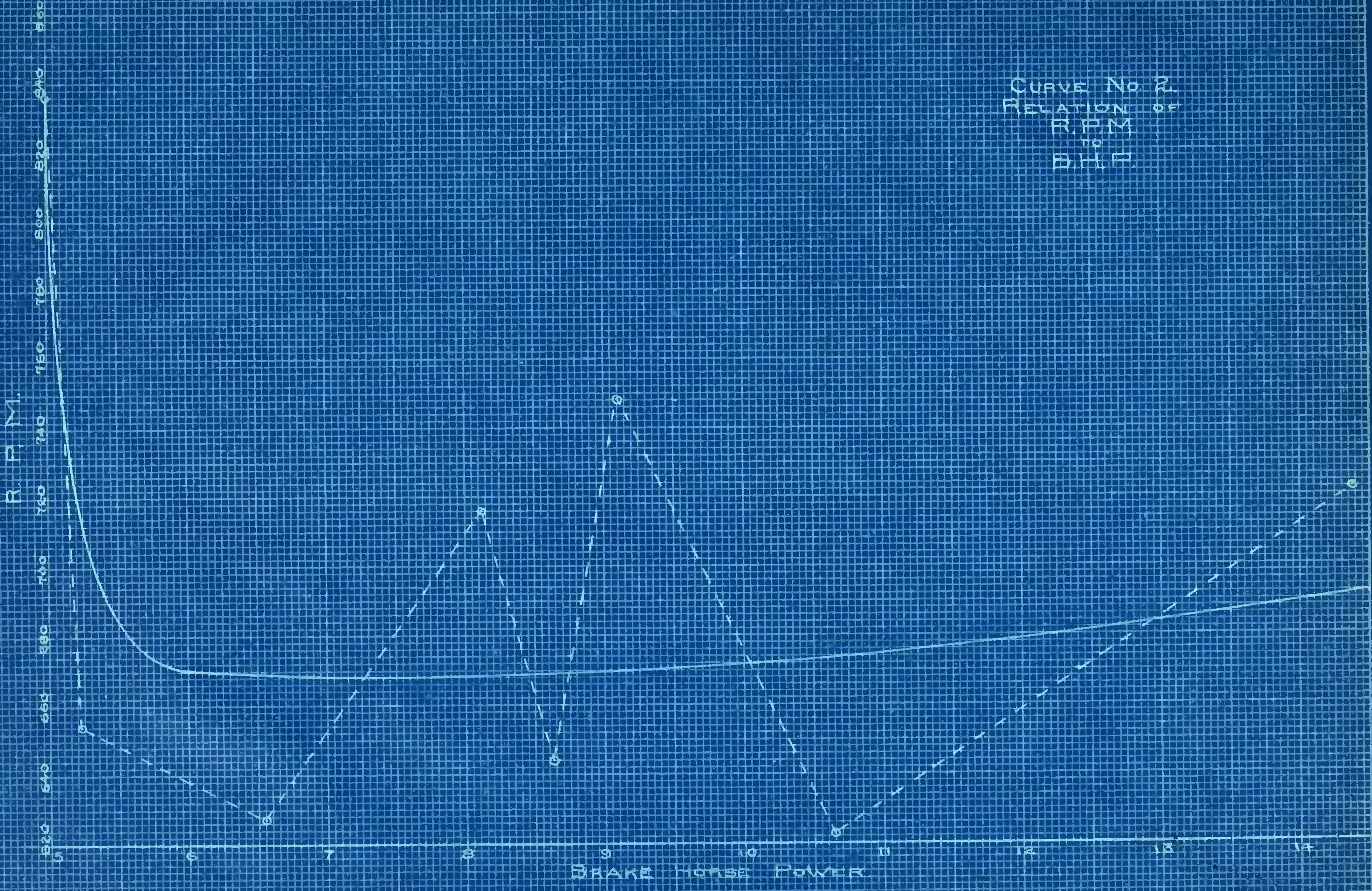
Date..................June, 3, 1907.
Run No...................................8
Duration of run.........................mins. 30
Gasoline consumed, Total...............cu. ft. .142
" " " ....gals. 1.061
" " " ....lbs. 6.36
Calorific value of gasoline...B. T. U. per lb. 19000
Jacket water supplied, Total.............lbs. 677
Gasoline consumed per hour.............cu. ft. .284
" " " " ....gals. 2.122
" " " " ....lbs. 12.72
Jacket water supplied per hour...........lbs. 1354
" " inlet........................°F. 52
" " outlet........................°F. 97.95
Gasoline in tank..........................°F. 72.75
Air in room...............................°F. 71
Revolutions per minute........................ 748.5
Explosions " " 1497
Builders' rating........................H.P. 20
Actual brake horse power...............B.H.P. 9.1
Heat supplied per hour.................B.T.U. 242,000
B. T. U. per B. H. P. per hour................ 26,600
" " " " minute.............. 443.33
Thermodynamic efficiency per B. H. P........%. 9.57
Gasoline per B. H. P. per hour.........cu. ft. .03121
" " " " " ....gals. .2334
" " " " " ....lbs. 1.4
Heat equivalent of B. H. P..................%. 9.57
" rejected in jacket water...............%. 25.7
" " " exhaust and lost through
m radiation and incomplete combustion.......%. 64.73

Observer:

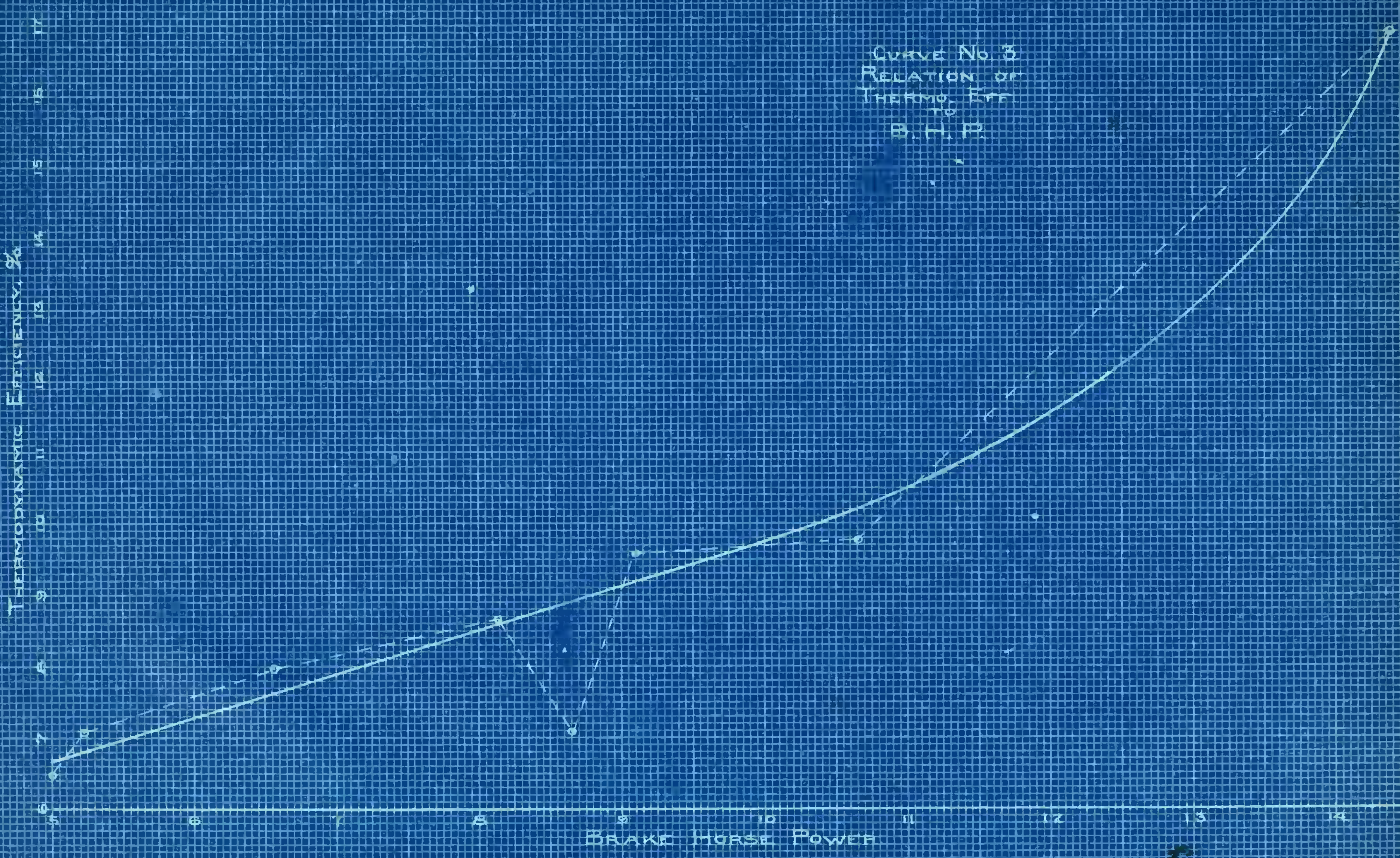
CURVE No. 1

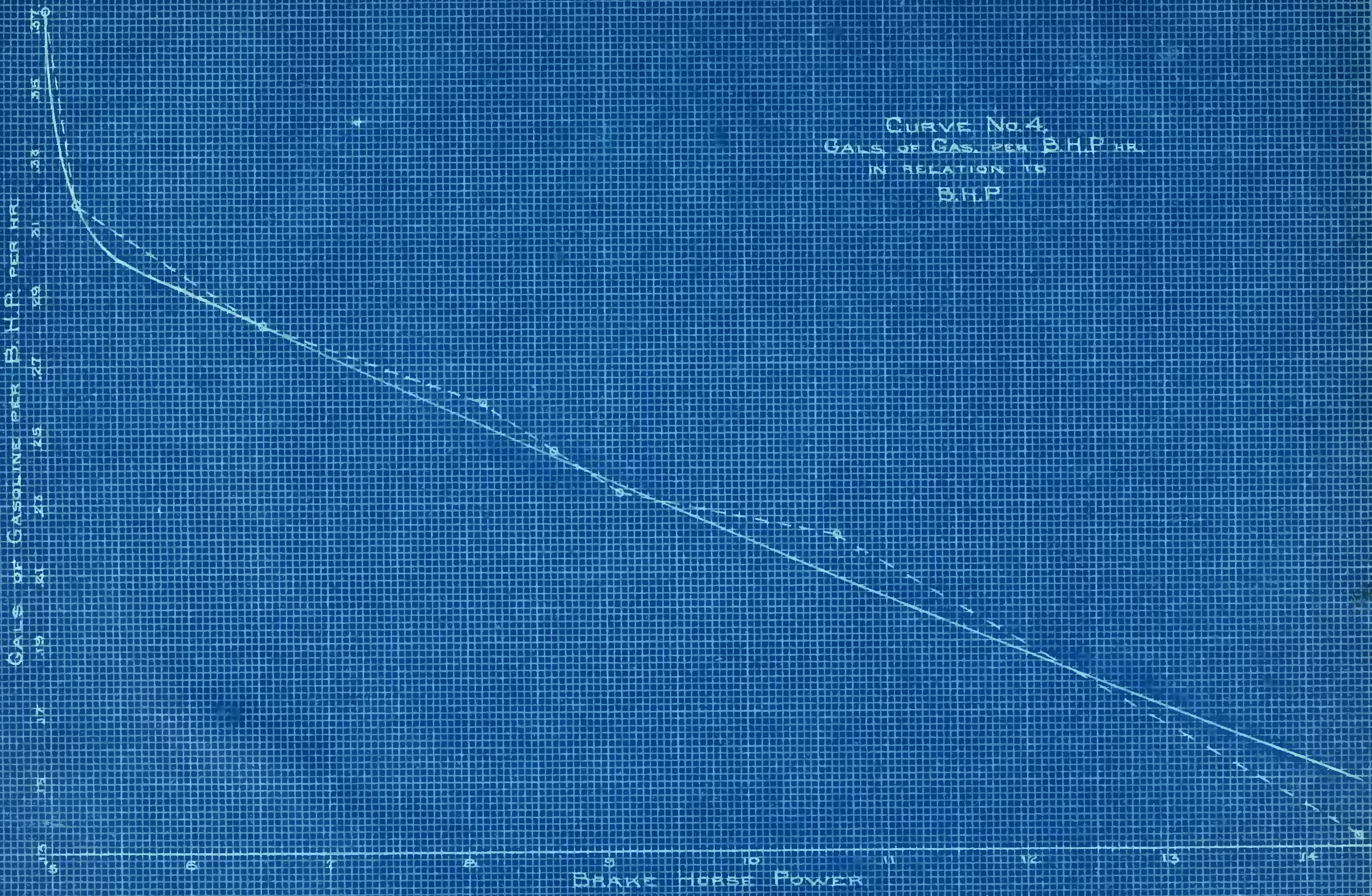
HEAT DISTRIBUTION.



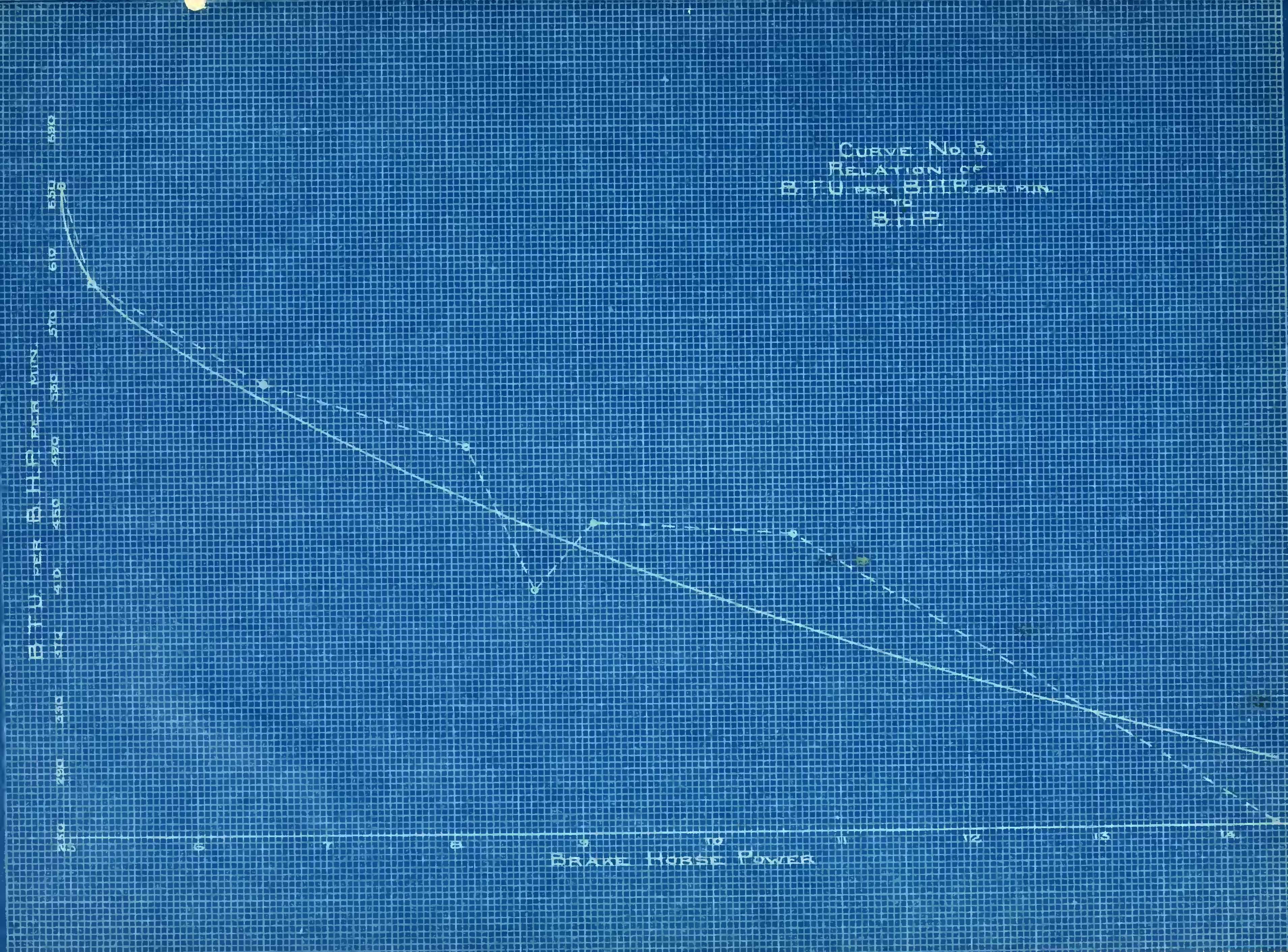


CURVE No 2.
RELATION OF
R.P.M.
TO
B.H.P.


Curve No. 3
Relation of
Thermo. Eff
to
B. H. P.
Thermodynamic Efficiency, %
6
7
8
9
10
11
12
13
14
15
16
17
Brake Horse Power
5
6
7
8
9
10
11
12
13
14



CURVE No. 4.
GALS. OF GAS. PER B.H.P. HR.
IN RELATION TO
B.H.P.


CURVE No. 5.
RELATION OF
B.T.U. PER B.H.P. PER MIN.
TO
B.H.P.
B.T.U. PER B.H.P. PER MIN.
250
290
330
370
410
450
490
530
570
610
650
690
5
6
7
8
9
10
11
12
13
14
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Respectfully
submitted

C. H. Smith